

DESCRIPTION

ALUMINUM PIPE AND PROCESS FOR PRODUCING SAME

5 CROSS REFERENCE TO RELATED APPLICATIONS

This application is an application filed under 35 U.S.C. §111(a) claiming the benefit pursuant to 35 U.S.C. §119(e) (1) of the filing date of Provisional Application No. 60/440,628 filed January 17, 2003 pursuant to 35 U.S.C. §111(b).

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TECHNICAL FIELD

The present invention relates to aluminum pipes, and more particularly to aluminum pipes useful as inlet pipes and outlet pipes in heat exchanges, such as condensers or evaporators for motor vehicle air conditioners wherein a chlorofluorocarbon refrigerant is used, gas coolers or evaporators for motor vehicle air conditioners wherein CO₂ refrigerant is used, motor vehicle oil coolers and motor vehicle radiators; as pipes for piping in motor vehicle air conditioners which have a refrigeration cycle adapted for use with a chlorofluorocarbon refrigerant, the refrigeration cycle comprising a compressor, condenser and evaporator which are interconnected by the piping; and as pipes for piping in motor vehicle air conditioners which have a refrigeration cycle adapted for use with CO₂ refrigerant, the refrigeration cycle comprising a compressor, gas cooler, intermediate heat exchanger, expansion valve and evaporator which are interconnected by the piping, and also to a process for producing

such pipes.

The term "aluminum" as used herein and in the appended claims includes aluminum alloys in addition to pure aluminum. Incidentally, the metal represented by an atomic symbol of
5 course does not include alloys thereof.

BACKGROUND ART

Condensers are known for use in motor vehicle air conditioners comprising a refrigeration cycle wherein a
10 chlorofluorocarbon refrigerant is used. Such condensers comprise a pair of aluminum headers arranged in parallel as spaced apart from each other, parallel flat heat exchange tubes made of aluminum and joined at their opposite ends to the headers, a corrugated aluminum fin disposed in an air passage
15 clearances between each pair of adjacent heat exchange tubes and brazed to the pair of heat exchange tubes, an inlet pipe of aluminum connected to one of the headers and an outlet pipe of aluminum connected to the other header.

The inlet pipe and the outlet pipe of the condenser
20 described are conventionally produced, for example, from JIS Al100, JIS A3003 or an alloy containing 1.0 to 1.5 wt. % of Mn, at least 0.2 wt. % to less than 0.6 wt. % of Mg, and the balance Al and inevitable impurities (see the publication of JP-B No. 1991-22459).

25 Also known is an aluminum pipe which is adapted for use in piping for motor vehicle air conditioners for interconnecting the compressor, condenser and evaporator thereof and which is made from an alloy comprising 0.3 to 1.5 mass % of Mn, up

to 0.20 mass % of Cu, 0.06 to 0.30 mass % of Ti, 0.01 to 0.20 mass % of Fe, 0.01 to 0.20 mass % of Si, and the balance Al and inevitable impurities, the matrix of the alloy containing particles of Si compounds, Fe compounds and Mn compounds which
5 include up to 2×10^4 particles, not smaller than $0.5 \mu\text{m}$ in size, per square millimeter (see the publication of JP-A No. 2002-180171).

Conventionally, a chromate surface treatment has been conducted for heat exchange tubes and inlet and outlet pipes
10 for the condensers and evaporators of motor vehicle air conditioners and pipes of aluminum piping for motor vehicle air conditioners mentioned above in order to give improved corrosion resistance to the tubes and pipes, whereas the treatment involves cumbersome work. Moreover Cr^{6+} is a
15 harmful substance, and the resulting liquid waste requires a troublesome treatment. Accordingly, condensers, evaporators and piping have the problem of necessitating troublesome work for production. Additionally, the use of Cr^{6+} is to be prohibited in Europe in the near future.

20 Thus, studies are under way on treatments of condenser or evaporator heat exchange tubes to be conducted as substitutes for the chromate treatment wherein harmful Cr^{6+} is used, for giving resistance to pitting corrosion and on tubes having resistance to pitting corrosion.

25 However, inlet and outlet pipes and pipes for piping which can be produced with ease at a lost cost and which have satisfactory resistance to pitting corrosion still remain to be developed. Of course, pitting corrosion resistance can

not be expected of the piping disclosed in the above two publications unless the pipes are subjected to the chromate treatment.

An object of the present invention is to overcome the above problems and to provide an aluminum pipe which can be produced easily and inexpensively and which has satisfactory resistance to pitting corrosion, and also a process for producing the pipe.

10 DISCLOSURE OF THE INVENTION

The present invention provides an aluminum pipe made from an alloy containing 0.90 to 1.50 mass % of Mn, and the balance Al and inevitable impurities, the pipe having an electrical conductivity of 30 to 43% IACS.

15 With the aluminum pipe of the present invention, Mn produces an effect to give the pipe improved resistance to pitting corrosion and an improved strength. If the Mn content is less than 0.90 mass %, this effect is not available. If more than 1.50 mass % of Mn is present, the effect to give an improved strength levels off, while hot working involves increased resistance to deformation to result in impaired workability, for example, lower extrudability, when the pipe is to be produced.

20 Accordingly, the Mn content of the alloy for making the pipe should be 0.90 to 1.50 mass %, and is preferably 1.0 to 1.2 mass %.

If the aluminum pipe of the invention is less than 30% IACS in electrical conductivity, the Mn content is insufficient to result in a lower strength, whereas if the conductivity

is over 43% IACS, sufficient amounts of solid solutions of Mn and inevitable impurities will not be formed to entail lower corrosion resistance. Accordingly, the alloy for making the aluminum pipe should be 30 to 43% IACS, and is preferably 33 to 37% IACS, in electrical conductivity.

Since the aluminum pipe of the invention is 30 to 43% IACS in electrical conductivity, the pipe can be prevented from pitting without being subjected to any chromate treatment.

Further because the pipe is made from an alloy containing 0.90 to 1.50 mass % of Mn and the balance Al and inevitable impurities, the pipe has an improved strength and can be produced with high workability. Moreover, the pipe can be produced merely by holding a pipe blank heated at a predetermined temperature in the atmosphere or in an inert gas atmosphere for a predetermined period of time and thereafter cooling the blank. The pipe can therefore be produced easily at a lost cost.

When the aluminum pipe of the invention contains Cu as an inevitable impurity, the content of Cu as such an impurity is preferably up to 0.05 mass % since Cu as an inevitable impurity is likely to give the aluminum pipe impaired resistance to pitting corrosion even if present in a very small amount. Thus, the Cu content is preferably up to 0.05 mass %.

In the case where the aluminum pipe of the invention contains Fe as an inevitable impurity, the content of Fe as such an impurity is preferably up to 0.25 mass % because Fe as an inevitable impurity is likely to give the aluminum pipe impaired resistance to pitting corrosion although less influential than

Cu. Accordingly, the Fe content is preferably up to 0.25 mass %.

In the case where the aluminum pipe of the invention contains Si as an inevitable impurity, the content of Si is preferably up to 0.25 mass % as an inevitable impurity because Si as such
5 an impurity, like Fe, has the likelihood of giving the aluminum pipe lower resistance to pitting corrosion. Accordingly, the Si content is preferably up to 0.25 mass %.

The process of the invention for producing an aluminum pipe is characterized in that a pipe blank made from an alloy
10 containing 0.90 to 1.50 mass % of Mn, and the balance Al and inevitable impurities is held heated at 550 to 600° C in the atmosphere or in an inert gas atmosphere for 10 to 600 minutes and thereafter cooled.

According to the aluminum pipe production process of the
15 present invention, the pipe blank is held heated at the specified temperature for the specified period of time, thereby permitting the Mn and inevitable impurities in the alloy making the pipe blank to form solid solutions in the matrix, whereby the crystals and precipitates contained in the material and
20 serving as nuclei for causing corrosion are diminished to give improved corrosion resistance. This results in a lower electrical conductivity and imparts improved resistance to pitting corrosion to the aluminum pipe produced. The heating temperature is 550 to 600° C because if the temperature is
25 lower than 550° C, sufficient quantities of solid solutions of Mn and inevitable impurities will not be formed in the matrix, and further because if the temperature is over 600° C, an economically poor efficiency only will result with no

improvement achieved in the effect to form solid solutions of Mn and inevitable impurities in the matrix. The blank is held heated for 10 to 600 minutes because if the period is less than 10 minutes, solid solutions of Mn and inevitable
5 impurities will not be formed satisfactorily in the matrix, and further because if the period is in excess of 600 minutes, an economically poor efficiency only will result with no improvement achieved in the effect to form solid solutions of Mn and inevitable impurities in the matrix.

10 The production process of the invention produces the aluminum pipe described above relatively easily at a lost cost.

In the aluminum pipe production process of the invention, the alloy for making the pipe blank is the same as that of the aluminum pipe of the invention with respect to the Mn content
15 and the contents of Cu, Fe and Si as inevitable impurities in the alloy.

With the aluminum pipe production process of the invention, the rate of rise in temperature for heating is preferably 20 to 130° C/min. The reason is that if the rate of rise in
20 temperature is less than 20° C/min, an economically impaired efficiency will result, and that if the rate is in excess of 130° C/min, it is likely that other products, such as aluminum tubes, to be heated along with the present aluminum pipe will not be heated at a uniform rate of rise in temperature.

25 In the aluminum pipe production process of the invention, the pipe blank heated is thereafter cooled preferably at a rate of at least 47° C/min because if the cooling rate is less than 47° C/min, Mn and inevitable impurities dissolved in the

matrix in the form of solid solutions will separate out again to possibly result in impaired corrosion resistance.

When the pipe blank is heated at the above rate of rise of temperature and/or cooled at the above rate, an economically high efficiency can be achieved, and the aluminum pipe produced is reliably given resistance to pitting corrosion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing a condenser which has an inlet pipe and an outlet pipe each comprising an aluminum pipe of the invention and which is adapted for use in motor vehicle air conditioners wherein a chlorofluorocarbon refrigerant is used. FIG. 2 is a diagram showing a heating pattern in Examples 1 to 4.

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BEST MODE OF CARRYING OUT THE INVENTION

An embodiment of the invention will be described below with reference to the drawing.

With reference to FIG. 1, a condenser 1 for use in motor vehicle air conditioners wherein a chlorofluorocarbon refrigerant is used comprises a pair of aluminum headers 2, 3 arranged in parallel and spaced apart from each other, parallel flat refrigerant tubes 4 (heat exchange tubes) made of aluminum extrudate and each joined at its opposite ends to the two headers 2, 3, corrugated fins 5 of aluminum brazing sheet each disposed in an air passage clearance between the adjacent refrigerant tubes 4 and brazed to the adjacent tubes 4, an inlet pipe 6 made of aluminum extrudate and connected to the upper end of

peripheral wall of the first 2 of the headers, an outlet pipe 7 made of aluminum extrudate and connected to the lower end of peripheral wall of the second 3 of the headers, a first partition 8 provided inside the first header 2 and positioned
5 above the midportion thereof, and a second partition 9 provided inside the second header 3 and positioned below the midportion thereof. The refrigerant tube 4 to be used may be an electro-resistance welded tube.

The number of refrigerant tubes 4 between the inlet pipe 6 and the first partition 8, the number of refrigerant tubes 4 between the first partition 8 and the second partition 9 and the number of refrigerant tubes 4 between the second partition 9 and the outlet pipe 7 decrease from above downward to provide groups of channels. A refrigerant flowing into
15 the inlet pipe 6 in a vapor phase flows zigzag through units of channel groups in the condenser before flowing out from the outlet pipe 7 in a liquid phase.

Each of the inlet pipe 6 and the outlet pipe 7 is made from an alloy containing 0.90 to 1.50 mass % of Mn, and the
20 balance Al and inevitable impurities. The pipe is 30 to 43% IACS in electrical conductivity.

The alloy for making the inlet pipe 6 and the outlet pipe 7 has an Mn content preferably of 1.0 to 1.2 mass %. The alloy for making the inlet pipe 6 and the outlet pipe 7 is preferably
25 33 to 37% IACS in electrical conductivity.

When the alloy for making the inlet pipe 6 and the outlet pipe 7 contains Cu as an inevitable impurity, the Cu content is up to 0.05 mass %. When the alloy contains Fe as an inevitable

impurity, the Fe content is up to 0.25 mass %. When the alloy contains Si as an inevitable impurity, the Si content is up to 0.25 mass %.

The inlet pipe 6 and the outlet pipe 7 are produced, for example, in the following manner.

The alloy described is extruded into an inlet pipe blank and an outlet pipe blank. These pipe blanks are held heated at 550 to 600° C in the atmosphere or in an inert gas atmosphere for 10 to 600 minutes and thereafter cooled. The rate of rise in temperature for heating is 20 to 130° C/min, and the rate of cooling after the heating is a least 47° C/min. In this way, the inlet pipe 6 and the outlet pipe 7 are produced.

The aluminum pipe of the invention according to the above embodiment is used as the inlet pipe and outlet pipe of the condenser of a motor vehicle air conditioner comprising a refrigeration cycle wherein a chlorofluorocarbon refrigerant is used. Alternatively, the aluminum pipe may be used as the inlet pipe and outlet pipe of the evaporator of the motor vehicle air conditioner. Furthermore, the aluminum pipe of the invention may be used as the inlet and outlet pipes of heat exchangers for use as motor vehicle oil coolers, motor vehicle radiators, etc.

Additionally, the aluminum pipe of the invention is useful for piping in motor vehicle air conditioners which have a refrigeration cycle adapted for use with a chlorofluorocarbon refrigerant, the refrigeration cycle comprising a compressor, condenser and evaporator which are interconnected by piping, and for piping in motor vehicle air conditioners which have

a refrigeration cycle adapted for use with CO₂ refrigerant, the refrigeration cycle comprising a compressor, gas cooler, intermediate heat exchanger, expansion valve and evaporator which are interconnected by piping.

- 5 The aluminum pipe of the invention may further be used in motor vehicle air conditioners which have a refrigeration cycle adapted for use with CO₂ refrigerant and comprising a compressor, gas cooler, intermediate heat exchanger, expansion valve and evaporator, as the inlet and outlet pipes of the
10 gas cooler and the evaporator.

Specific examples of the invention will be described below along with comparative examples.

Examples 1-4

- Four kinds of alloys having the respective compositions
15 listed in Table 1 were extruded into pipe blanks 9.53 mm in outside diameter and 1.0 mm in the wall thickness of peripheral wall.

[Table 1]

Example	Composition (mass %)					Conductivity (IACS)	Max. corrosion depth (μm)
	Al	Mn	Cu	Fe	Si		
1	Bal.	1.12	0.01	0.12	0.03	33.8	233
2	Bal.	1.09	0.01	0.15	0.05	37.0	209
3	Bal.	0.90	0.01	0.22	0.07	36.8	306
4	Bal.	1.07	0.01	0.23	0.07	40.1	494

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The pipe blanks were then placed into a preheating furnace set at an internal furnace temperature of 500° C, held in the

furnace for 10 minutes, thereafter placed into a main heating furnace set at an internal furnace temperature of 601° C and held at a blank temperature of 600° C for 3 minutes, whereupon the pipe blanks were cooled to a blank temperature of 570° C with nitrogen gas. The blanks were thereafter withdrawn from the main heating furnace. The rate of rise in temperature for heating was 30° C/min, and cooling rate was 60° C/min. FIG. 2 shows the heating pattern.

The pipes thus produced were checked for electrical conductivity. Table 1 also shows the result.

The pipes were subjected to SWAAT 960 hr test and checked for resulting corrosion. Table 1 shows the maximum depth of resulting corrosion in the pipes. Table 2 shows the state of corrosion in the pipes, i.e., the depth of corrosion and number of corrosive faults.

[Table 2] Corrosion in the Pipes

Example 1		Example 2		Example 3		Example 4	
Depth of corrosion (μm)	N*	Depth of corrosion (μm)	N*	Depth of corrosion (μm)	N*	Depth of corrosion (μm)	N*
Up to 100	3	Up to 100	4	Up to 100	3	Up to 100	1
100-200	3	100-200	7	100-200	10	100-200	6
200-300	1	200-300	0	200-300	2	200-300	4
300-400	0	300-400	0	300-400	1	300-400	0
400-500	0	400-500	0	400-500	0	400-500	1

N*: Number

Comparative Examples 1-4

Four kinds of alloys having the respective compositions listed in Table 1 were extruded into pipe blanks 9.53 mm in

outside diameter and 1.0 mm in the wall thickness of peripheral wall, and the pipe blanks were subjected to SWAAT 960 hr test without heat treatment and checked for the resulting corrosion.

The pipes were found to have pits extending through the
5 peripheral walls thereof due to corrosion.

INDUSTRIAL APPLICABILITY

The aluminum pipe of the present invention is suitable as inlet pipes and outlet pipes in heat exchanges, such as
10 condensers or evaporators for motor vehicle air conditioners wherein a chlorofluorocarbon refrigerant is used, gas coolers or evaporators for motor vehicle air conditioners wherein CO₂ refrigerant is used, motor vehicle oil coolers and motor vehicle radiators; as pipes for the piping in motor vehicle air
15 conditioners adapted for use with a chlorofluorocarbon refrigerant and comprising a compressor, condenser and evaporator which are interconnected by piping; and as pipes for piping in motor vehicle air conditioners adapted for use with CO₂ refrigerant and comprising a compressor, gas cooler,
20 intermediate heat exchanger, expansion valve and evaporator which are interconnected by the piping.